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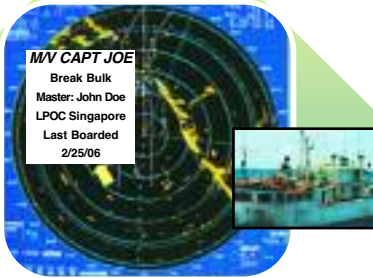
Strategic MDA

Applying fusion technologies to Maritime Domain Awareness.

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Persistent awareness in the maritime domain requires the critical need to process massive amounts of data in time periods that support engagement strategies. Two critical elements point to the need for automated fusion tools:

- the massive amounts of data to be fused, mined, and analyzed and
- the numerous dimensions to be fused, mined, and analyzed.

From an operational perspective, operation centers would be challenged to keep up with the demand to hire the analysts necessary to process the vast amounts of maritime data and information. From a technical perspective, the processes that are needed become significantly more complicated by the disparate and dissimilar natures of the data evidenced by the vast number of data sources and data types. Applying these complex data fusion and analysis tools to the operational community will require the technologists and operators to work closely together.

In response to the need for fusion tools, the Department of Homeland Security's Science and Technology Advanced Research Projects Agency and the United States Coast Guard's Director of MDA, under the guidance of the "National Plan to Achieve Maritime Domain Awareness," executed a study to identify and understand the various current fusion efforts, characterize the technologies needed to achieve MDA, identify gaps between current and required fusion capabilities, and develop MDA fusion. Data collection started in September 2005 and continued through February 2006. Throughout the course of the study, more than 120 fusion-related projects were identified across many government organizations and academia with technologies that could potentially be applied to Maritime Domain Awareness fusion needs.

The study defines "data fusion" as the process of combining data or information to determine what significant, actionable knowledge is present in all available data. Within the MDA environment, an entity represents a person, physical object, concept, relationship, or an event. Therefore, data fusion within the context of MDA can mean estimating or predicting entity states, determining relationships, assessing situations, or assessing potential impacts or threats. Data within the maritime domain is available in diverse forms. In current operations, sensors (or other technical means) gather data about physical objects, while data about people and relationships are made available through several avenues including cargo manifests, crew lists, and ship routes.

Data fusion researchers and developers understand the complex algorithms necessary to fuse massive amounts of maritime data. The data structures and the relationships between entities rapidly become very complex when the mathematicians include the uncertainties associated with the data. Both the customers and users of fusion tools will need to work closely together to understand the behavior of the fusion tools, as well as the uncertainties associated with the data sources. Quantifying the uncertainty in the data will enable these automated fusion technologies to track alternative associations and help the operators manage the vast amounts of data.

Automated data-fusion technologies will be critical to help the operational community process the increasingly massive quantifies of data. Today, operators and analysts are able to only process, in real time, a fraction of the available MDA data. The introduction of a nationwide automatic identification system and many other new dynamic data sources can only contribute to the challenge that tomorrow's operators will

have to manually process Maritime Domain Awareness data, unless action is taken to adopt automated fusion tools.

Fusion Study

The data fusion study team sought information on data fusion applications residing in operational and research and development systems that may apply to processing data within the maritime domain. Two MDA fusion workshops were held with participation and representation from the Department of Homeland Security, Department of Defense, Department of the Navy, and the Department of Energy.

The final report includes descriptions of existing data-fusion projects and raises the awareness in the complex nature of these advanced fusion concepts and technologies. Figure 1 consolidates a list of fusion applications, identifies fusion enabling technologies, and ultimately provides an overall assessment of the state of data fusion technologies applied to MDA. Several technologies in the report could be applied to solve the Maritime Domain Awareness data fusion challenge.

The study identified that many of the automated technologies are primarily in advanced R&D stages, where fairly mature applications were developed against a specific type of data. Very few of the applications were capable of performing the automated all-source data fusion necessary to process the massive amounts of maritime data and information. Implementing these automated data-fusion tools requires the use of complex mathematically and statistically based solutions and the information, at various stages of processing, needs to be easily understood by operators and analysts. Training programs will need to include familiarization with the methodologies being applied to fuse data.

Government feedback to the data fusion report has been consistent with the findings of the study. Most agree that the data-fusion solution will depend on data-sharing policies, as well as the utility of the fusion technologies.

Challenges

Additional technological challenges identified in the report include sharing data and information, a necessary enabler for fusion and analysis of conveyances, cargo, and people. Data and information will need to freely flow between national intelligence and law enforcement agencies throughout the national and port levels (Figure 2). Information pertinent to the maritime domain resides in databases owned by many government departments and agencies, spanning all levels of security used by the intelligence community and those used by law enforcement.

The global counterterrorism campaign includes entities within the maritime domain and requires fusion and analysis of data and information from various databases, and a broad range of open-source information. These data sources reinforce the need for data fusion technologies and applications to extend past the traditional sensor-fusion applications to include all MDA-relevant data and information with a common set of vocabularies and processes.

MDA Data Fusion and the Way Ahead

There are more than 30 highly relevant applications that could be leveraged and applied to the MDA
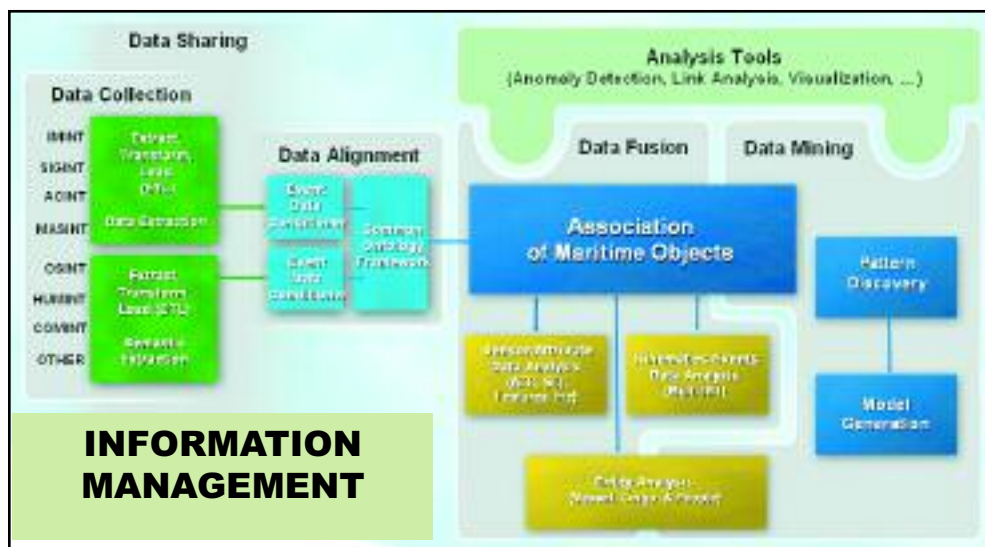

Figure 1. MDA Data Fusion Context Diagram. Graphic courtesy of Johns Hopkins University Applied Physics Laboratory.

fusion challenge. The government could focus resources on select projects and take a phased research and engineering process to integrate existing technologies and focus research and development resources on quantifying the performance of these tools.

Transitioning automated data fusion and analysis tools into the operational environment requires confidence in the ability of the automated tools to perform
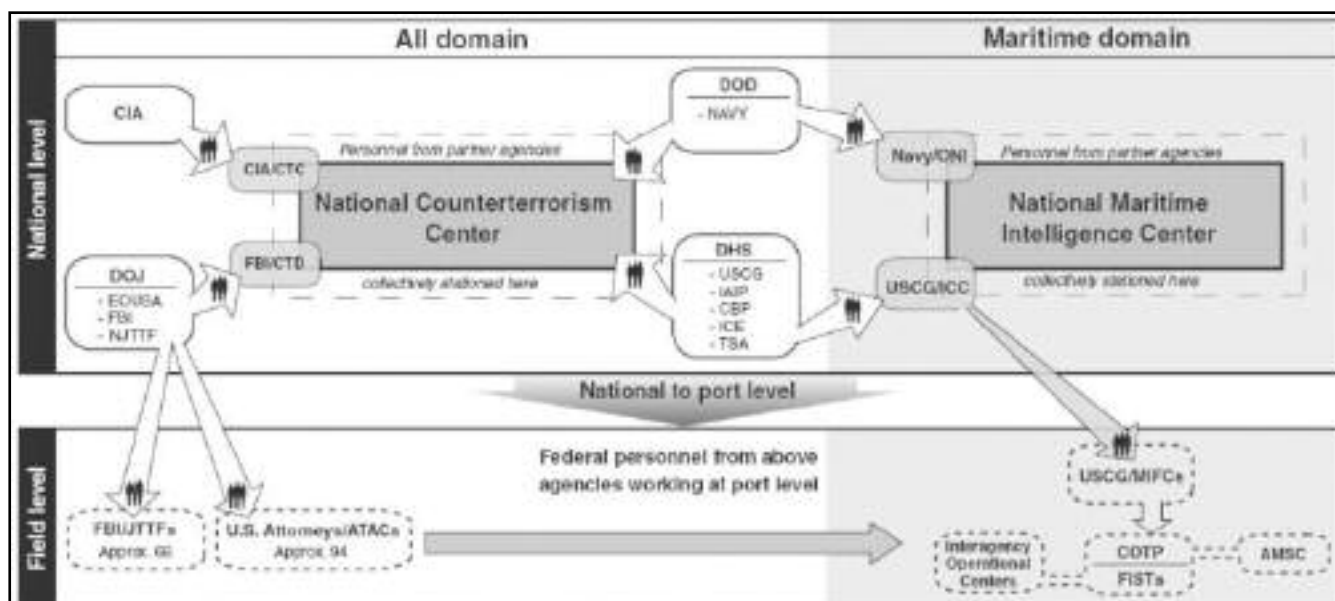
Figure 2. Flow of information between national intelligence and law enforcement agencies and between the national and the port level. Graphic reprinted with permission from the "Maritime Security report to Congressional Requestors," GAO-05-394, April 2005.

just as well or better than today's operators and supporting tools. Data fusion performance criteria, measures of performance, and metrics already exist throughout government, academia, and industry. These subject matter experts, especially within maritime organizations, need to work together (within the acquisition process) and define a technical evaluation process to measure the utility of these fusion tools.

Recommended next steps include establishing a collaborative, networked environment that supports the MDA community. This will allow three key processes to be initiated:

· Implement currently available tools and applications (with varying degrees of automation) to utilize the potential of the network environment to provide a baseline level of capability to the operating forces.
· Establish a phased, technical evaluation process to characterize fusion engine applicability, performance, and utility through testing, and to understand the limits of each component.
· Develop an iterative operational evaluation process with user feedback to establish an initial baseline. Effectiveness will be measured through analysis of operational use and overall contributions. The operational evaluation, coupled with the technical evaluation will determine which components should be integrated into the fusion applications federation.

Relevant science and technology efforts must be coordinated across government agencies, industry, and academia to augment and leverage MDA community investment in fusion, considering both short- and long-term requirements.

There is little doubt that achieving Maritime Domain Awareness is essential to the security of our maritime boarders. MDA could benefit from an interagency program that has oversight across the Department of Defense, the Department of Homeland Security, and the intelligence community to define policy, strategies, and resources essential to achieve persistent awareness in the maritime domain.

About the author:
Mr. Eric Tollefson is the Maritime Domain Awareness program manager for the Johns Hopkins University Applied Physics Laboratory. Mr. Tollefson has worked in private industry for a contractor developing fusion solutions for underwater acoustic systems. He has published papers on topics related to data fusion technologies and applications in operational environments. Mr. Tollefson is a graduate of the University of Phoenix and holds a Bachelor's degree in Business and Information Systems, as well as a Master's degree in Computer and Information Systems.